RF POWER METER

Ramsey Electronics Model No. PM50

Ever need to tune up RF equipment, but didn't have the money for expensive watt meters and spectrum analyzers? Want to be able to measure low-level signals and high-level signals without changing slugs and flipping switches? This versatile piece of test equipment should be standard on every RF experimenter's bench.

- **Can accurately measure signals from –30dBm to +47dBm, that's <10 microwatts to 50 Watts!**
- **Peak hold function accurately shows peak power.**
- **Press a button and have automatic conversion between dBm and Watts. Display auto-scales all readings.**
- **Low battery indication and voltage monitoring.**
- **High contrast LCD display for easy viewing and long battery life!**
- **Runs from 7-15V AC or DC or 9VDC battery. Use our AC1 wall adapter for long operation.**
- **Display reads from –30dBm (1uW) to +47dBm (50Watts).**
- **Highly accurate (+-1dB) from 100kHz to 450MHz. Effective up to 900MHz, [you will need to do the math against our included chart] –3dB at 500MHz.**
- **LED indicators clearly show current auto-ranging power scale.**
- **Perfect match for tuning and testing our various transmitters such as the FM100B, FM25B, PX1, AM1, AM25, and the QRP line of transmitters. Tune your product for maximum efficiency!**
- **Look at the PBF10 for monitoring of power while transmitting.**

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- **FM100B Professional FM Stereo Transmitter**
- **FM25B Synthesized Stereo FM Transmitter**
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PM50 HIGH RANGE RF POWER METERKIT MANUAL
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KIT ASSEMBLY AND INSTRUCTION MANUAL FOR

PM50 HIGH RANGE RF POWER METER

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PM50 INTRODUCTION

Welcome to the PM50 kit (and if you didn't have time to build a kit, the wired and tested version!). This great little product works so well our technicians are using them here at the shop as their bench-top power meter of choice. The kit is based around an AD8307 log detector which has a 90dB dynamic range for signal strength measurements. Tie that with a nice 50 watt dummy load and a fan-cooled heatsink and you have yourself a very easy to build and calibrate power meter!

The handiest part of the power meter is its ability to measure very small signals, such as the RF from low-power transmitters such as our FM10A. This meter allows you to accurately tune the last stages of a transmitter's filter or gain stages for maximum efficiency and transmission range. Without this power meter you might have to simply go with your best guess.

For larger high-power fields you can put a calibrated antenna on the input and measure signals as small as –30dBm; from this you can easily calculate field strength, the very thing the FCC would do if they tested your radio station. You can now check your transmitter for compliance. You'll need to find a calibrated antenna to rent but they are available.

We hope you enjoy building this kit as we had a lot of fun designing it for you. To keep costs down we have miniaturized the kit to fit in our standard plastic case and panels and left the detector board separate so its heatsink can get plenty of ventilation to keep it cool when you are applying heavy loads.

In the interest of preserving battery power we chose to use a CPU heatsink and fan combination. Then we motor speed control the fan so that it only runs when there is power to be dissipated. For power measurements under 5 watts there is no need to run the fan so your battery life is extended. Over 5 watts the fan speed will vary from about 1/4 speed to full speed depending on power applied.

PM50 THEORY OF OPERATION

Our goal in this section is that you will come away from this theory with a greater understanding of electronics, dBm, and how power is measured from transmitters. You may also learn why this power meter has such a fantastic range and you will find out why our engineer (me) has such a bad headache after writing a routine to convert an analog to digital value to dBm and then to watts using nothing but assembly language on an 8-bit processor. The C language equivalent just wouldn't fit in such a small microcontroller.

The heart of the power meter is the combination of the 50 Watt thin-film 50 ohm resistor. This is a nifty part in that it has excellent characteristics for being used as a dummy load saving us a lot of expense of more complex solutions and making this kit more affordable. This 50 ohm load is tied directly across the

BNC jack, so any RF coming into the unit from a transmitter simply sees this "perfect" 50 ohm load, rather than the complex load of an antenna or a less than ideal load.

Next in line is the AD8307 log detector IC. This IC has a range of roughly –80dBm to +12dBm. This translates to a range of 92dB! This is simply amazing since it converts this range to a linear dB to volts output, which can then be sampled by an analog to digital converter. Since 50 Watts translates to +47dBm we see that this little part would be overwhelmed by such a high signal. So to remedy this we put a 37dB attenuator in line between the dummy load and the AD8307. This means +47dBm becomes +10dBm, and –30dBm becomes –67dBm. We will see later why this becomes our minimum effective value in the future rather than –80dBm.

The AD8307 outputs a clean 25mV per dB of signal seen, so if we run this signal into an A/D converter we can convert this 25mV/dB into a usable number for further calculations. In our case we are using a 12-bit A/D converter to maximize resolution and accuracy. For our dB range of the detector (-37dBm to +47dBm) this comes out to a output voltage range of 0.4V to 2.5V. Now if we have the converter set up to convert between 0-2.5V, this means we have a potential accuracy of 2.5 / numSteps or 2.5 / 2^12 or 610uV per step, or in other words 610uV / 25mV/dB = .024dB per step. A fair bit of resolution to start with!

Before going directly to the analog to digital converter however, we do some signal conditioning on the output with U5:A, which is a non-inverting amplifier and low-pass filter. The low-pass filter helps to remove noise and higher-frequency changes in power level like AM signals to give us a better average power reading. DC-wise this has a gain of 1+Rf/Ri or 1+10K/1K or 1.1. This means our 25mV per dB now becomes 27.5mV per dB. We simply adjust the code to scale the numbers differently.

You may notice we also use U5:B as a comparator to compare the 0.4V reference to the AD8307 output. When we calibrate the PM50 we sample the output of the comparator with the microcontroller to make sure the base line adjustment with no power input is very slightly above the reference voltage. This lets the display determine if we are close to a calibrated output. The PM50 didn't really need this, but I had an extra opamp on U5 to put to use, so why not? Anyway a comparator works by using the high open-loop gain of an opamp of 100,000 or more. If pin 5 (+) is higher than pin 6 (-) the difference is multiplied by 100,000 and sent to the output. If the difference is 0.001V, the output winds up going as high as it can, 5V. If the difference is –0.001V, the output goes as low as it can, in this case 0V.

U3 is an amazing little part, with accurate timers, a 10-channel 8-bit analog to digital converter, all sorts of interrupts and more; there's a heck of a lot you can do with this tiny part. We take advantage of a lot of features of this part in this project. Why? Just because they're there! In our case we are mostly doing math and the rest is user interface such as looking at the switch and updating the display.

We put one of the internal A/D converter channels to use in the microcontroller so we can sample the battery voltage. This is done with a simple voltage divider consisting of R8 and R9. It simply divides the battery down to be within the range that the A/D can accept which is 0-5V. By sampling the battery voltage we can determine if it is time to replace the battery because our readings may become compromised. Our readings become bad when the 5V regulator can no longer regulate because the battery voltage is too low. This means all of our reference voltages will be off too, since they are derived from the 5V of the regulator. In the case of my code, I blink the colons so you know the battery voltage is too low. Also the voltage is displayed when you press and hold the mode switch.

Another module in the microcontroller has an accurate timer and compare functions. We put one to use for controlling the CPU fan and regulating its speed. A timer and compare module can be used as a pulse width modulator (PWM) which in turn is used as a motor speed controller. Basically the fan is turned on and off at a fast enough rate that the average speed is affected, but not so slowly that it turns on and off. The longer the fan is turned on vs. how long it is off affects the speed the fan will go at. This is performed via a timer compare output on the micro controller running directly to Q1, a BS170 MOSFET. When a low (0V) signal comes from the micro controller, Q1 is off, therefore the fan is off. When a high (5V) signal comes from the micro controller Q1 is on, and so is the fan. For more information on how motor speed controlling is performed, see the MSC-1 kit.

In our case we only start the fan at incoming signals above 5 watts. The heatsink can easily dissipate 5 watts without the fan running, so why waste the battery? For powers over 5 watts, I use a floating average routine. This routine is neat in that it works very much like a capacitor, numerically charging and discharging through a numeric resistor. You can see the basic premise of the formula for this as follows:

```
Sum = Sum + Input
Sum = Sum / numPoints
Output = Sum / numPoints
```

This formula is called each time the display is refreshed, and the input and output are both power. Then we simply use the power (if it above 5 watts) to vary the speed of the fan. An example of how the numbers works is below when numPoints = 4. Amazing how output looks just like a capacitor charging in the circuits shown in figure 1! Basically it is a very simple DSP method. The resistor values are determined by how fast I call the routine, and the capacitor by numPoints. Cool? Are your eyes glassed over yet?

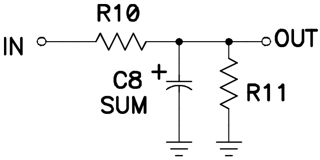
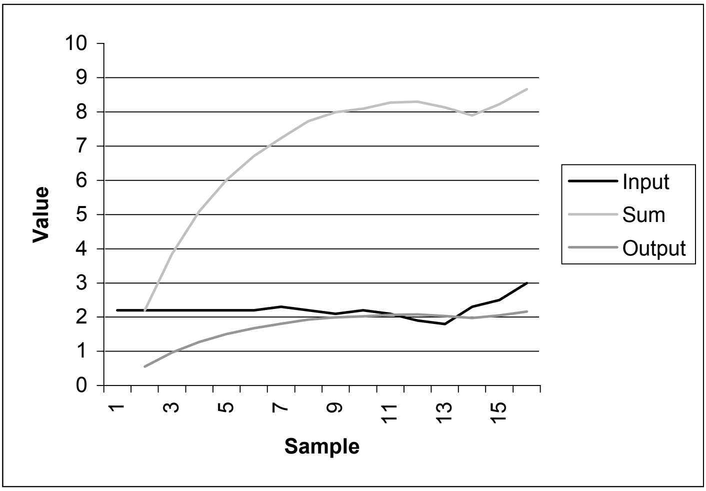


FIG 1.

Input	Sum	Output
2.2		
2.2	2.20	0.55
2.2	3.85	0.96
2.2	5.09	1.27
2.2	6.02	1.50
2.2	6.71	1.68
2.3	7.23	1.81
2.2	7.73	1.93
2.1	7.99	2.00
2.2	8.10	2.02
2.1	8.27	2.07
1.9	8.30	2.08
1.8	8.13	2.03
2.3	7.90	1.97
2.5	8.22	2.06
3	8.67	2.17



One last thing to cover is the power supply. Since this product requires very little power we have a very simple power supply. D4 and C15 are what is called a half-wave rectifier. This means that if you decide to use an AC adapter only the energy in the positive half of the AC cycle is used for the kit. This 1/2 of the AC cycle is used to charge C15 which essentially “smoothes” out the pulses from the diode to give use something more resembling DC. C15 isn’t perfect, so VR1 then takes this still bouncy voltage on C15 and smoothes it out even more. In order to do this, it essentially chops off the rough edges.

For battery operation D3 provides protection from the AC supply to prevent the battery from charging incorrectly when AC power is applied. But we make a necessary sacrifice with D3 because we lose 0.7V for the voltage drop across the diode. This is important because we need at least 2V over the regulated output of VR1 to allow it to regulate properly. In the case of the 78L05 we need about 2V above the 5V to regulate, so 7V. The diode adds another 0.7V to this for a total of 7.7V. This is the lowest our battery voltage can go and still have your kit give accurate readings. The microcontroller looks at the voltage and tests to see if it is 7.7V or not to let you know when it’s time to replace the battery.

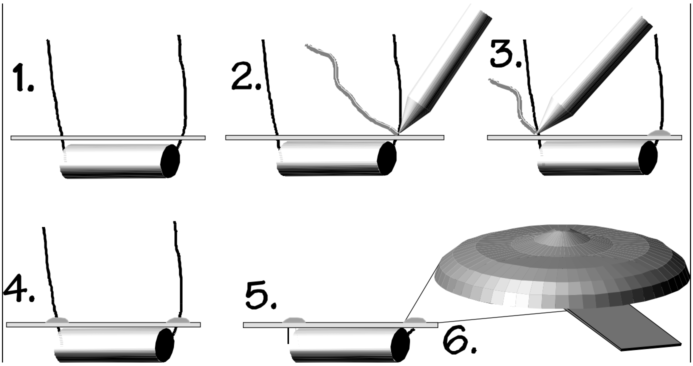
RAMSEY "LEARN-AS-YOU-BUILD" ASSEMBLY STRATEGY

Be sure to read through all of the steps, and check the boxes as you go to be sure you didn't miss any important steps. Although you may be in a hurry to see results, before you switch on the power check all wiring and capacitors for proper orientation. Also check the board for any possible solder shorts, and/or cold solder joints. All of these mistakes could have detrimental effects on your kit - not to mention your ego!

Through-hole part installation:

Use a good soldering technique - let your soldering iron tip gently heat the traces to which you are soldering, heating both wires and pads simultaneously. Apply the solder on the iron and the pad when the pad is hot enough to melt the solder. The finished joint should look like a drop of water on paper, somewhat soaked in.

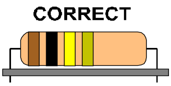
Mount all electrical parts on the top side of the board provided. The top side is clearly marked with the word "TOP"; you can't miss it. When parts are installed, the part is placed flat to the board, and the leads are bent on the backside of the board to prevent the part from falling out before soldering (1). The part is then soldered securely to the board (2-4), and the remaining lead length is then clipped off (5). Notice how the solder joint looks on close up, clean and smooth with no holes or sharp points (6).

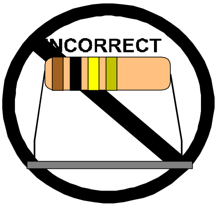


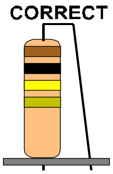
This is a mixed signal project meaning there are digital and RF circuits all in one unit. As with all RF circuitry, we want to mount the parts AS LOW AS POSSIBLE to the board. A 1/4" lead length on a resistor not mounted close to the board can act as an inductor or an antenna, causing all sorts of problems in your circuit. Be aware though that there are stand up components in your circuit. They don't need to be squished to the board, but keep the portion of the resistor closest to the board mounted right on the board.

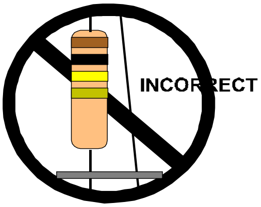
For each through-hole part, our word "Install" always means these steps:

☐ 1. Pick the correct part value to start with.
☐ 2. Insert it into the correct PC board location, making sure the part is mounted flush to the PC board unless otherwise noted.









☐ 3. Orient it correctly, follow the PC board drawing and the written directions for all parts - especially when there's a right way and a wrong way to solder it in. (Diode bands, electrolytic capacitor polarity, transistor shapes, dotted or notched ends of IC's, and so forth.)
☐ 4. Solder all connections unless directed otherwise. Use enough heat and solder flow for clean, shiny, completed connections.

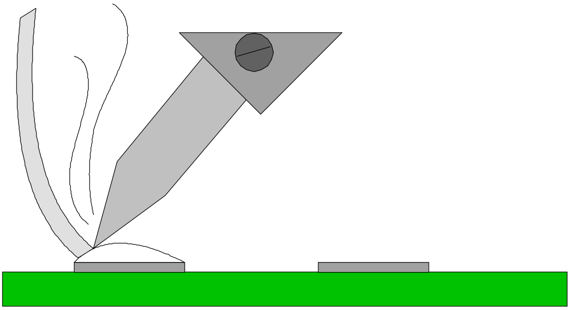
Surface Mount part installation:

Check all received parts against the Parts list. The parts list describes the various markings that may be found on the kit parts.

In the case of a surface mount component, INSTALL means these steps:

- Melt a small amount of solder on one pad on the PC board in the location of the component you wish to install. Usually choose pin 1 on ICs.

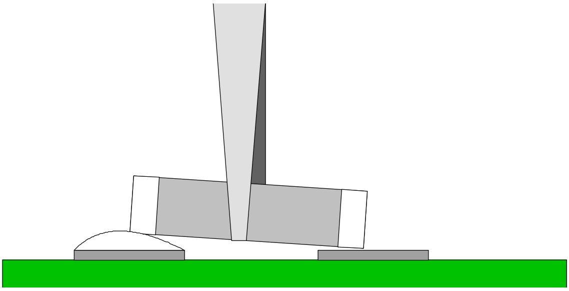
- Locate the part from one of the bags.



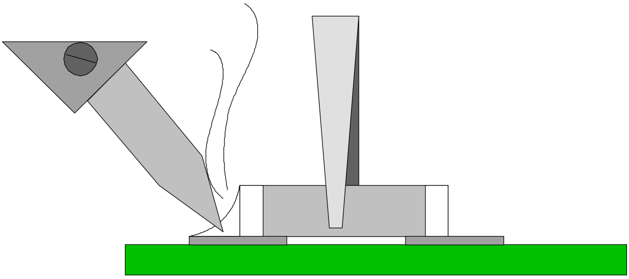
- Use tweezers to pick up the part, grabbing it across the body of the part and not the solder connections.

- Place the part in the assembly location. Use one hand to hold the tweezers and part in place.

- Use the other hand to reheat the solder dab to melt it to the component connection.

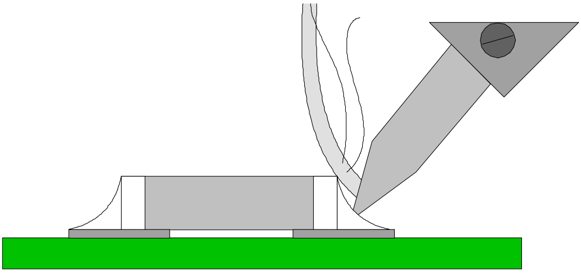


- Let the solder cool and let go with the tweezers. Inspect orientation and make sure the part is square, flat, and oriented over the correct pads. Also make sure a connection doesn't overlap or short across adjacent pads.



- Apply solder to the rest of the pads.

- Apply a touch more solder to the initial pad to make sure there is a good solder joint.



- If you have too much solder and wish to remove it use a solder sucker or solder wick to “mop up” the extra solder. Solder bridges on SMT IC pins are a frequent occurrence so you should always have some solder wick handy.

Enough said. . . Let's get building!

You are going to want to use a VERY clean desk space to assemble your surface mount kit. Drop a resistor into even the smallest amount of clutter, and it will disappear like magic, in fact you would swear a magician was hovering over your shoulder in some cases when part after part disappears. There are probably enough parts hidden in the papers on my desk to hide an entire communications system, but we won’t go there.

Use only one surface mount part at a time; don’t pour them out all over the desk. Retrieve a single component, place the part on the desk, and then pick it up with the tweezers. This lets you orient the part so the markings are on the top. It also provides you with Tiddly Winks practice; *Ping* and you hear the part bounce off of the wall and down into the heat register. If you are really careful this won’t happen.

NOTE TO NEWCOMERS: If you are a first time kit builder you may find this manual easier to understand than you may have expected. Each part in the kit is checked off as you go, while a detailed description of each part is given. If you follow each step in the manual in order, and practice good soldering and kit building skills, the kit is next to fail-safe. If a problem does occur, the manual will lead you through step by step in the troubleshooting guide until you find the problem and are able to correct it.

RAMSEY PM50 PARTS LIST

Main Board:

Semiconductors

- ☐ 2 1N4002 Rectifier Diode (Black body with white stripe marked 4002) (D3,4)
- ☐ 1 78L05 5V Voltage Regulator (Marked 78L05 in transistor-like pack -age) (VR1)
- ☐ 1 ADS7816PC 12-Bit serial analog to digital converter, 8-pin DIP. (U4)
- ☐ 1 BS170 MOSFET Transistor marked BS170 (Q1)
- ☐ 1 LMC662CN Rail to Rail CMOS dual Op-amp (U5)
- ☐ 1 Custom Programmed MC68HRC908JK3 (U3).
- ☐ 1 MM5452 LCD Controller shift-register (U2)
- ☐ 1 4-Digit LCD display
- ☐ 3 Small yellow LEDs (D1,2,5)

Capacitors and Inductors

- ☐ 1 10pF ceramic capacitor (Marked 10 or 10K) (C6)
- ☐ 7 0.01uF ceramic capacitors (Marked 103) (C3,4,5,11,18,19,20)
- ☐ 4 0.1uF ceramic capacitors (Marked 104) (C1,2,9,10)
- ☐ 3 10uF electrolytic capacitors (C12,13,16)
- ☐ 1 1000uF electrolytic capacitor (C15)
- ☐ 2 1.5uH inductors (Green body, brown-green-gold) (L1,2)

Resistors

- ☐ 1 10 ohm resistor (brown-black-black) (R7)
- ☐ 3 47K ohm resistors (yellow-violet-orange) (R3,4,9)
- ☐ 1 100K ohm resistor (brown-black-yellow) (R18)
- ☐ 1 150K ohm resistor (brown-green-yellow) (R8)
- ☐ 3 330 ohm resistors (orange-orange-brown) (R1,5,6)
- ☐ 1 1.0K ohm resistor 1% (brown-black-black-brown) (R15)
- ☐ 1 2.0K ohm resistor 1% (red-black-black-brown) (R2)
- ☐ 1 10.0K ohm resistors 1% (brown-black-black-red) (R1)
- ☐ 1 13.0K ohm resistor 1% (brown-orange-black-red) (R20)

Hardware, Misc.

- ☐ 1 Power Switch (S2)
- ☐ 1 Small push-button switch (S1)
- ☐ 1 2.1mm Power Jack (J2)
- ☐ 1 2.5mm Stereo Jack (J4)
- ☐ 2 2.5mm male stereo jacks.
- ☐ 1 16-Pin dual row connector (J3,J4)
- ☐ 1 6-Pin single row connector (J1)

Detector Board:

Semiconductors

☐ 1 AD8307AR Log detector (U30)

Capacitors and Inductors

☐ 1 0.001uF ceramic 0805 surface mount capacitor (C33)
☐ 2 0.01uF ceramic 0805 surface mount capacitors (C32,35)
☐ 2 0.1uF ceramic 0805 surface mount capacitors (C31,34)
☐ 1 10uF electrolytic surface mount capacitor (C30)

Resistors

☐ 1 50K surface mount trim pot (R34)
☐ 2 1K ohm 0805 resistors (R33,R35) (Marked 102)
☐ 1 8.2K ohm 0805 resistor (R30) (Marked 822)
☐ 1 51 ohm 0805 resistor (R32) (Marked 51)
☐ 1 0 ohm resistor (Marked 0) which will be used for calibration in place of R33.
☐ 1 50 Ohm thin-film power resistor (R31)

Hardware, Misc.

☐ 1 PC Board mounted BNC Connector (J30)
☐ 1 2.5mm Stereo Jack (J31)
☐ 1 6-Pin single row connector (J31)
☐ 1 3-Pin single row connector (J32)
☐ 3 4-40 x 3/8” stainless machine screws.
☐ 4 4-40 1” standoffs.
☐ 2 4-40 Washers.
☐ 1 Vial of heat-sink compound.
☐ 1 6-Conductor 1 foot long ribbon cable.
☐ 1 CPU heatsink and fan assembly.

Note: 1% resistors read a bit differently than 5% resistors. For example a 10K ohm resistor in the 5% method would be Brown for 1, black for 0, orange for 3 places after the last defined digit, and then gold to identify the part as a 5% component. So 1-0-000 ohms +-5%.

A 1% 10.0K resistor needs to identify one more place of precision than a 5% resistor does, so it includes an extra stripe. In this case it would be brown for 1, black for 0, another black for another 0, red for two remaining zeros, and a brown to indicate 1%. So 1-0-0-00 +-1%. It is easy to mix up what end is what on these resistors, because either end begins with brown. Typically the precision stripe (which is always last) is wider than the rest, kind of like a period. So always start from the end with the narrow stripe.

DISPLAY ASSEMBLY

Assembly of your PM50 is fairly straightforward and surprisingly simple. We will assemble things in three different steps to keep things organized.

☐ 1. We will begin with the display board. If this has not been done for you already you will need to break off the display board from the main board along the line of holes or score marks. If necessary, place the line of holes along the edge of a table top and press down on the board to snap it off. Afterwards you may find there is a lot of material hanging off the edge. This is fiberglass. Use a file to smooth the edges down so it isn't as sharp.

☐ 2. Install U2, the MM5452 40-pin IC. This IC is critical in placement and orientation since there is no desoldering of this after the display board is fully assembled. The LCD display will eventually be mounted directly over the top of this IC, so the chip needs to be mounted as flush as possible. U2 doubles as a spacer for the display so that it looks nice from the front panel. Be sure to mount it on the top of the board (same side as the silk screen).

Solder just one pin, check alignment and flushness, then solder all of the rest of the pins.

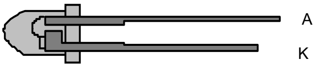
The next few parts are not marked on the PC board silkscreen. Simply follow the directions for orientation.

☐ 3. Install C3, a 0.01uF ceramic capacitor (Marked 103). This is mounted on the back side of the PCB, opposite from where we just installed U2.

☐ 4. Install C4, another 0.01uF ceramic capacitor (Marked 103). This is also mounted on the back of the board. We mount these two on the back to keep the front of the board nice and clean, since we will be able to see it through the front panel.

☐ 5. Install R3, a 47K ohm resistor (yellow-violet-orange). Again, this is mounted on the back of the PC board. This resistor in combination with C4 sets up a timing clock for U2. U2's outputs constantly change to maintain the on and off states of the LCD. LCDs segments cannot be turned on by DC, only by AC. DC will actually damage the segments after some time.

☐ 6. Install S1, the small pushbutton switch on the same side as U2. Note the switch can only be installed in one direction; don't force it in the wrong way!



☐ 7. Install D5, one of the small yellow LEDs. These LEDs will indicate the range the display is showing for the auto-ranging function. Note how the LEDs have a long lead and a short lead. The long lead is the Anode. And since these are diodes they can only be correctly installed in one direction. The Anode needs to be oriented toward the switch, and the cathode (short lead) needs to be oriented towards the top edge of the board. These LEDs are all mounted flush to the board.

☐ 8. Install D2, another of the yellow LEDs. This LED is in the same orientation as D5 with the Anode lead toward the switch.

☐ 9. Install D1, the last of the yellow LEDs in the same orientation with the Anode in the same orientation as D5.

☐ 10. Install DS1, the LCD display. This is actually very tricky since the leads don't go all the way through the board. It will actually be top-soldered, but before you solder you have to make sure all of the pins are in their respective holes. To give you an idea how hard this is, it took me over 10 minutes to get my prototype board lined up. This was partly due to my bad drilling skills, so yours should be much easier.
The orientation of the display is important as well, and it isn't clearly marked on the display. If you look very closely at the front of the display you will see a small lump on one end and a little line in the LCD material itself. This is the LCD manufacturer's indication of pin 1, since the display seems to work in this direction. Pin 1 orientation should be the same as U2's.
Once you have the pins lined up, top-solder one of the pins in place, preferably a center pin like pin 10. This will keep the display from rocking and becoming crooked as you solder the rest of the pins. This stage is where a mini-vise is really helpful.

☐ 11. Take the 16-pin dual row connector and cut it in half to make two 2-row 8 pin connectors.

☐ 12. Install the one in the position marked J5 on the side of the board opposite the display (The back side).

☐ 13. Install the other in the position marked J6 on the side of the board opposite the display. The two connectors we just installed make it very easy to mount the main board and the display board together.

The display panel is now complete. We will eventually be attaching this display panel to the main board, but we will get to that later. If we attached it now it would be very difficult to install parts on the main board later, especially the power switch. On the next page we will begin working on the main board.

MAIN BOARD ASSEMBLY

We are now going to build the main board. This is where the brains of the project are. It contains the microcontroller (U3) and the 12-bit analog to digital converter, as well as some signal conditioning (U5).

U3 is truly an amazing part, being a small computer contained in a single chip. This part takes the raw conversion data from our analog to digital converter and does some math to it to find dBm or watts then formats the data for display on the LCD.

We will begin from the back of the PCB and work towards the front.

☐ 14. Install C19, a 0.01uF ceramic capacitor (marked 103).

☐ 15. Install L2, one of the 1.5uH inductors (green body marked brown-green-gold).

☐ 16. Install L1, another 1.5uH inductor (green body marked brown-green-gold).

☐ 17. Install Q1, the BS170 MOSFET transistor. This is used to control the fan speed. Watch orientation of this part!

☐ 18. Install R7, a 10 ohm resistor (brown-black-black). This resistor prevents shorting out of the main board power supply when the power detector board is plugged into J4. It, combined with L1, L2, C19, and C18, also provides the function of filtering. They simply prevent high levels of RF from going back into our sensitive circuitry when higher power RF signals are being worked with.

☐ 19. Install J1, the 6-pin single row connector. This is a bit different since the part is surface mounted instead of through-hole. Solder the short ends of the connector to the surface of the board. To make it easy, put some solder on the pad for pin 1, then hold the part in place and heat to hold the part in position. Once cooled, you can then solder the rest of the pins.

☐ 20. Install C18, a 0.01uF ceramic capacitor (Marked 103).

☐ 21. Install R16, a 10.0K ohm 1% resistor (brown-black-black-red).

☐ 22. Install C9, a 0.1uF ceramic capacitor (Marked 104). This capacitor on the opamp circuit makes for a low pass filter for the output of the log detector before going to the A/D converter. This prevents conversions of noise which can cause error.

☐ 23. Install R15, a 1.0K ohm 1% resistor (brown-black-black-brown).

☐ 24. Install C16, a 10uF electrolytic capacitor. Note that electrolytic capacitors are polarized, meaning they can only be installed in one direction to operate properly. Pay close attention to the markings on the electrolytic capacitors. Typically the capacitors are marked with a stripe to indicate the negative lead. We mark our PC boards with a + sign. Just install the stripe on the capacitor opposite from where our + symbol is and the part will be installed correctly!

☐ 25. Install C11, a 0.01uF ceramic capacitor (Marked 103).

☐ 26. Install R19, a 10.0K ohm 1% resistor (brown-black-black-red).

☐ 27. Install R20, a 13.0K ohm 1% resistor (brown-orange-black-red).

☐ 28. Install R2, a 2.0K ohm 1% resistor (red-black-black-brown). These last three resistors form a voltage divider to give us our various reference voltages which conversions are based against. These three resistors give us the 2.5 volt full-scale reference, and the 0.4 volt conversion base. Signals being sampled by the converter are compared to these two voltages so it is important that they are accurate, therefore 1% resistors are used.

☐ 29. Install C2, a 0.1uF ceramic capacitor (Marked 104).

☐ 30. Install C1, a 0.1uF ceramic capacitor (Marked 104).

☐ 31. Install U5, the LMC662 dual rail to rail opamp. Make sure you orient pin one which is indicated by a notch or dot on the part to the notch indicated on the silkscreen. We have to use a rail-to-rail opamp in this project since we are running the opamp from +5V which isn’t a lot of voltage for a standard opamp like a LM358 to work with. Standard opamps cannot usually get within 0.7 volts of the supply voltage, and we need to get down to 0.4V.

☐ 32. Install U4, a ADS7816P 12-bit serial analog to digital converter. This will take analog voltages from the log detector and convert them to a digital value that the microcontroller can understand. It does this with a fair amount of precision making this an accurate kit for testing.

☐ 33. Install C20, a 0.01uF ceramic capacitor (Marked 103). This capacitor will help U3 reset properly when you power on the kit.

☐ 34. Install C6, a 10pF ceramic capacitor (Marked 10 or 10K).

☐ 35. Install R4, a 47K ohm resistor (yellow-violet-orange). This resistor combined with C6 sets the operating frequency of U3, the microcontroller. We have it conservatively set at 1MHz to save on battery power. This means a slower screen update time, but if it went too fast it would be hard to make good readings.

☐ 36. Install C10, a 0.1uF ceramic capacitor (Marked 104).

☐ 37. Install C12, a 10uF electrolytic capacitor. Pay close attention to orientation!

☐ 38. Install R9, a 47K ohm resistor (yellow-violet-orange).

☐ 39. Install C5, a 0.01uF ceramic capacitor (Marked 103).

☐ 40. Install R8, another 150K ohm resistor (brown-green-yellow). R9, C5, and R8 are a simple voltage divider which divides the 9-15V supply voltage down into the 0-5V range so we can make sure the battery is still good for making accurate readings. The VR1 voltage regulator requires the battery voltage to be at least 7V, so once the battery voltage gets below this, accuracy begins to falter. This is indicated by the blinking colons on the display when the battery gets low. The divided output is sent to one of the pins of the microcontroller which is used as a simple 8-bit A/D converter.

☐ 41. Install U3, the microcontroller. Usually this will have a sticker on top indicating software revision. If not, it is marked 68HRC908JK3. Make sure to align the notch or dot with the notch on the silkscreen so that pin 1 is in the correct orientation.

☐ 42. Install R6, a 330 ohm resistor (orange-orange-brown).

☐ 43. Install R1, a 330 ohm resistor (orange-orange-brown).

☐ 44. Install R5, a 330 ohm resistor (orange-orange-brown). These three 330 ohm resistors limit current to the yellow LEDs so their brightness is matched and U3 isn’t overloaded.

☐ 45. Install C13, a 10uF electrolytic capacitor. Again pay close attention to the orientation! This capacitor helps VR1 to regulate our supply voltage to +5V.

☐ 46. Install VR1, the 78L05 voltage regulator. Yes, this looks like a transistor, but it is actually a voltage regulator. Note the orientation of the flat side of the part; it must be installed in the same direction as shown. This does the work of taking the slightly filtered battery or adapter voltage and converting it to a nicely regulated +5V for our logic circuits and our reference voltages.

☐ 47. Install C15, 1000uF electrolytic capacitor. Be sure to orient it correctly as this cap will make a big bang if installed backwards. Follow the PC board silkscreen for proper orientation.

☐ 48. Install D4, a 1N4002 type rectifier diode. This diode is used to convert AC from an AC adapter to DC. It will also pass DC from a DC adapter, and also prevent damage from using a DC adapter with the wrong connections. As an AC rectifier, it is called a half-wave rectifier. This means that only the positive half of an AC cycle is used to power the circuit. C15 smoothes the pulsed DC from this half-wave rectifier so that VR1 can regulate it properly.

☐ 49. Install D3, another 1N4002 type rectifier diode. While this diode reduces the voltage output of the battery it also saves us when we have the battery in and then plug in AC power. Without this diode, the battery would try to charge but probably explode instead. This diode is a safety measure. If you want to extend the useful life of the battery and **never** plan on running the PM50 on AC, install a jumper here instead, and remove D4.

☐ 50. Install J4, the 2.5mm stereo jack. This jack will provide power to the sensor board, and also give us back the detected signal level.

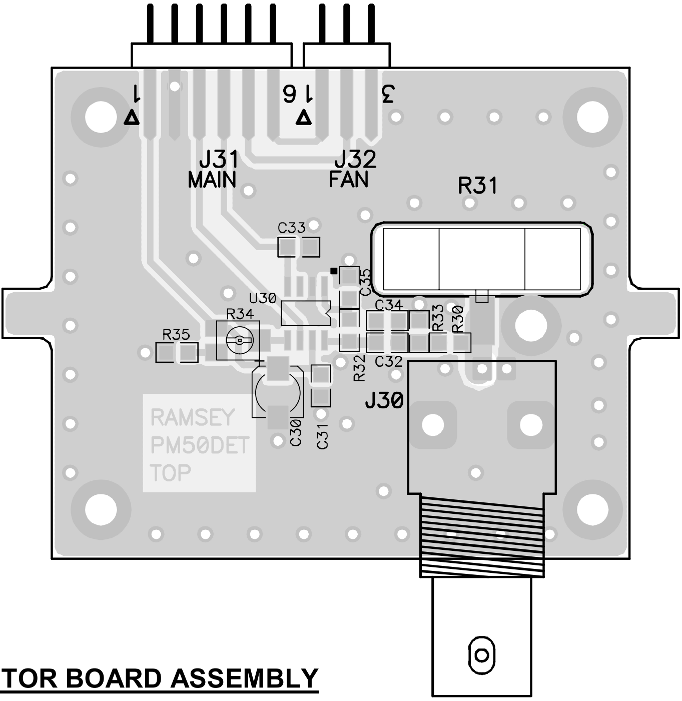
☐ 51. Install J2, the 2.1mm power jack.

☐ 52. Install S2, the power switch. Make sure and mount this nice and square so that it will protrude from the display panel properly once assembled.

☐ 53. Install BAT1, the battery clips. Note that the red wire goes into the hole marked +, and the black goes into hole marked –.

☐ 54. Install the battery clip using two small pieces of spare wire lead soldered first through the board and then to the clip. Note the two small holes provided for this purpose. They should be nipped pretty close to the clip when done so that it doesn't prevent the battery from clipping in properly.

This ends the main board build section! Now get out your special eyes and tools because we are going in headfirst to play Tiddly Winks with some really small components. On to making our detector board!



DETECTOR BOARD ASSEMBLY

Note: This section may be assembled for you already. If you have purchased the pre-assembled surface mount version of the kit you can skip this section. Otherwise follow each step closely here; it is a challenge for sure!

We are now going to build the detector board. This section uses surface mount parts so we are going to need a lot of patience with this part of our project. Refer to the strategy section if you need a refresher on how to install surface mount components. Just take your time, be careful, and things will go smoothly.

Organize your work area before you begin, and clean off any unnecessary junk before you start so that you can keep the area clean.

☐ 55. Install C33, a 0.001uF SMT ceramic capacitor. Note that many surface mount capacitors are not marked, so it is up to you to keep things organized so they don't get mixed up.

☐ 56. Install C35, a 0.01uF SMT ceramic capacitor.

☐ 57. Install R32, a 51 ohm SMT resistor (Marked 51.).

☐ 58. Install C32, a 0.01uF SMT ceramic capacitor.

☐ 59. Install C34, a 0.1uF SMT ceramic capacitor.

❒ 60. Install the zero ohm SMT resistor in place of R33 (Marked 0). We will eventually replace this with a 1K ohm SMT resistor (Marked 102).)

❒ 61. Install R30, an 8.2K ohm resistor (Marked 822).

❒ 62. Install U30, the AD8307 8-pin SOT8 packaged log detector IC (say that ten times fast!). Before soldering you may note that there is no dot or notch on the end of the part to indicate pin one. If you look closer you will see that one whole side of the part has a sloped edge, where the other does not. This sloped edge indicates the edge where pin one is, so you will need to use that as your reference for orientation. Align this with the dot we provide on the silkscreen which also indicates pin 1. Every manufacturer has their own ideas on how pin one should be indicated so we are rarely lucky enough to have it match the layout every time!

❒ 63. Install C30, a 10uF electrolytic capacitor. Note that just like its bigger brethren, it must be installed in the correct orientation. If you look closely at the black plastic base, there is one end that is beveled. This indicates the + side of the capacitor; just match this bevel up with the bevel we show on the silkscreen.

❒ 64. Install C31, a 0.1uF SMT ceramic capacitor.

❒ 65. Install R35, a 1K ohm SMT resistor (Marked 102).

❒ 66. Install R34, a 50K ohm trimmer. This will be used to adjust our dBm offset or zero power level. Make sure that it is centered over the pads provided. If it is off-center it could potentially short underneath, which is difficult to debug later.

❒ 67. Install J30, the board mounted BNC connector.

❒ 68. Install J31, a 6-pin single row connector. Surface tack it like we did on the main board, soldering the short ends to the board.

❒ 69. Install J32, a 3-pin single row connector. This connector is for the fan. Again solder the short ends to the board.

Note that we will not be installing the 50 ohm power resistor yet we are saving that for the heatsink stage. We don’t want to break the lead during assembly since there is only one small wire to hold it place. If it breaks off, it is a very expensive little part!

At this point you will want to go over your work and check for any mistakes. With surface mount components it is good to use a magnifier even if you have excellent eyesight. Check for shorts between leads, blobs of solder which cross over two pins, and components installed in the incorrect orientation.

HEATSINK ASSEMBLY

At one time we were struggling to figure out what to use for a heatsink for this kit, but I happened to stumble into the IT room and found the perfect solution! A good old CPU heatsink and fan assembly. They are made in such quantities that they are inexpensive and widely available. All we had to do is add a few holes for you to screw into and it was a perfect solution!

Check the drilled holes for burrs and any lumps which may prevent flush mounting of the board to the heatsink. Use a sharp knife to carve off any irregularities. Put a small amount of thermal compound between the two screw holes on the heatsink where the resistor will soon be mounted. A blob about the size of a pinhead will do. Any more and it may cause problems with connectivity! While thermal compound is a good heat conductor, it is a poor electrical conductor, and we need both.

Locate the included 1” standoffs and use them to screw down the board to the heatsink. You will note that there is a bevel side to the heatsink; you will need washers between the board and the heatsink on this side to keep spacing even to prevent the board from flexing too much when you tighten things up. Tighten snugly, but don’t over-tighten; aluminum will strip easily.

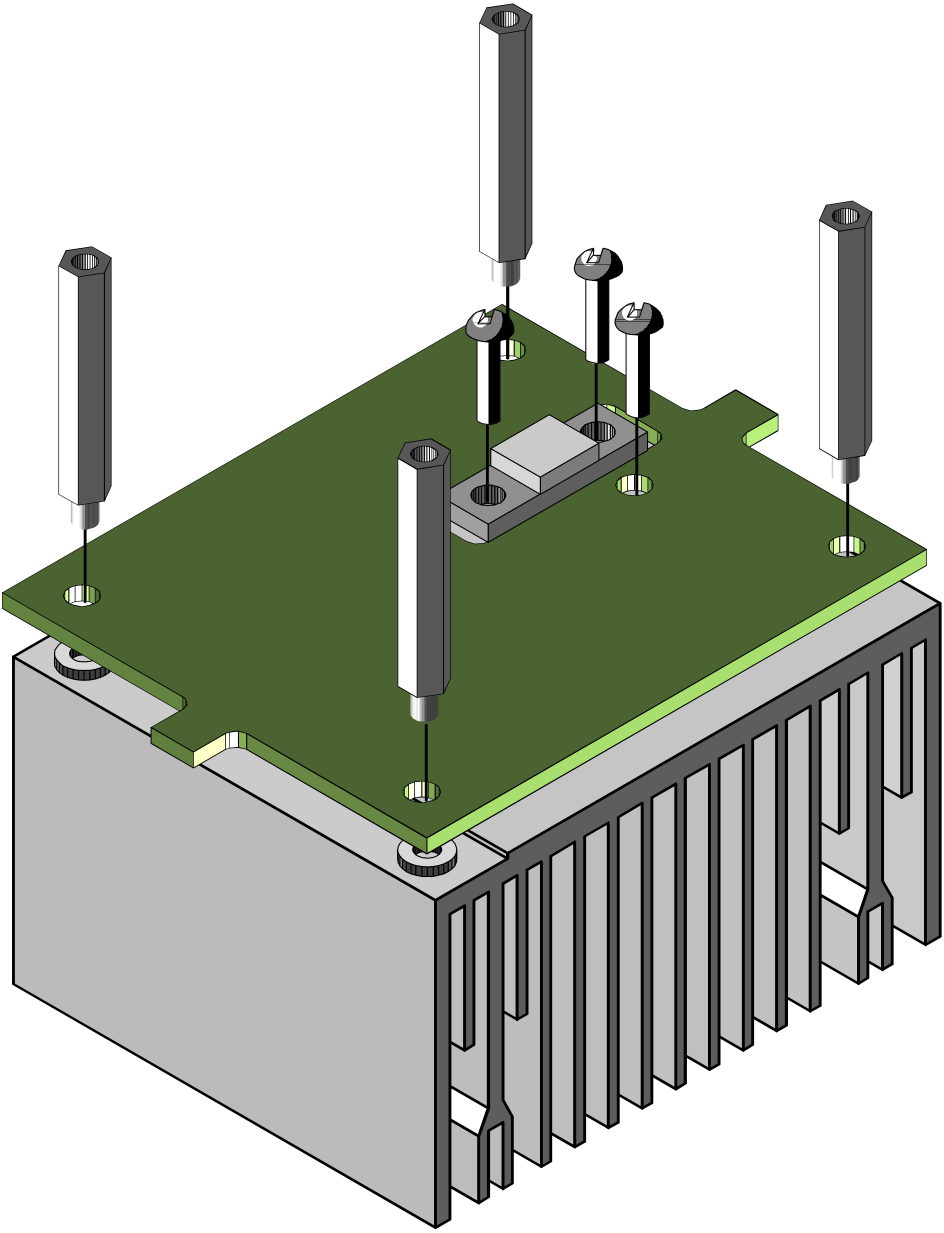
Locate R31 and trim the one connector lead in half. Then, using two of the included 4-40 x 3/8” stainless screws, mount the resistor down so that you can solder the lead to the PCB properly. Be sure to tighten this snugly; we want the resistor to have a good electrical and thermal connection to the heatsink. Now go ahead and solder the lead to the board.

Install the last screw in the mounting hole near where the resistor was installed. This is actually for an electrical connection more than anything and makes for a good solid ground between R31 and the PC board.

Now you can solder down the resistor to the detector PCB. Check your work!

Use the heatsink clip to grab hold of the two tabs on the PC board and firmly hold everything in place.

HEATSINK ASSEMBLY DIAGRAM



FRONT AND MAIN BOARD MOUNTING

In this final step of assembly we will be joining the main board to the display board. You will need to use ample solder for this step as it not only is used for making electrical connections, but also for mechanically joining the two boards.

☐ 1. Locate the front and main board. Note how they are supposed to go together, aligning the large hole on the front panel to the power switch, and also note the alignment of the connectors and pads which will be used to “glue” the two boards together.

☐ 2. Align the display board with the main board so that the connector’s pins line up with the pads on both the top and bottom of the board.

☐ 3. Solder a single lead and check for orientation. The front panel should be mounted as close as possible to the main board. We don’t want the front panel to be too far away from the main board or the display will no longer fit into the case.

☐ 4. While the main and display board are held squarely together, begin soldering together the two using the pads provided.

☐ 5. Make sure all of the provided pads are joined.

☐ 6. Check your work for shorts! It is fairly easy to correct these problems if you do it now. And you definitely want to find any errors before you apply power.

WIRING THE DETECTOR POD

For your convenience we have pre-made the cables needed to interconnect the detector pod with the main board. Normally this would be difficult to do on your end, since a special tool is used to press the wires into the connectors. All you have to do is make sure you connect pin 1 to pin 1. There is no key, so this is easy to confuse. Pin 1 is indicated by the triangle symbol on the PC board.

Also, the fan connector has no key so you will need to note that pin 1 of the fan cable is the black wire.

Go ahead and connect these all together and you should have a completely assembled kit!

It is probably a good time to check over the main board for assembly problems or forgotten steps and also to check the detector board again. You may be surprised at the mistakes you find after you look away for a bit.

TESTING THE PM50

To begin testing the PM50 we will need the following items:

- ❍ AC Power supply between 8 and 12VAC or..
- ❍ DC power supply between 8 and 14VDC.
- ❍ Or 9V DC battery
- ❍ A signal source to confirm measurement like an FM10A, RF signal generator (preferable) or simply a long antenna.

The very first thing you want to do is recheck your assembly. Make sure your ICs are installed in the correct orientation, electrolytic capacitors are in the correct direction, and that there are no solder bridges or cold solder joints. All parts should be flush to the board.

If you have worked with calibrating equipment before you have probably heard about a little nasty called a transfer function. A transfer function is really a curve-fitting program allowing you to match the output of a sensor (in our case the detector board) with the physical display. We have found that the AD8307 is amazingly accurate with slope, meaning you will almost always have 25mV out per dB. The offset can vary quite a bit from unit to unit.

To further complicate matters, it is hard to get an accurate baseline for noise to adjust to. In this case we are going to temporarily short out the detector board's input to reduce detected noise as much as possible to find an accurate baseline. If you followed your assembly instructions you will have installed a 0 ohm resistor in place of R33; this provides the short we need.

Plug in the power to your PM50, and check the cable between the detector board and the main board. Hold down the mode switch when powering the unit on, this will get the PM50 into a calibration mode so you can adjust the base line properly. The display will now show you the direct output of the analog to digital converter in the range of 0-4095.

Using a small screwdriver, adjust R34 on the detector board so that the display reads 001-002, which means you've adjusted the baseline of the detector to the base line of the Analog to digital converter.

Power down the PM50, and remove the 0 ohm resistor from the R33 position. Now you can install the 1K ohm SMT resistor where R33 is supposed to be (Marked 102).

Power up the PM50, and connect your signal source. Verify a good power reading!

If you have a calibrated source like a top quality signal generator you can calibrate your unit for even more accuracy. Since the baseline does vary slightly from unit to unit it will give your PM50 a +-2dB accuracy. If you can calibrate with a known signal level you will achieve better than +-1dB accuracy.

Instead of going to the calibration screen on power up, simply plug the signal generator into the detector board. Set your generator for the highest amplitude possible (as long as it is less than 50 watts!) at 100MHz. Adjust R34 of the detector board until the display matches your generator output. Reduce the level 20dB and check the reading to be sure it is within +/- 0.5dBm. If the reading is not that close there may be a problem in the U5 circuitry of R15 and R16. You are done.

USING THE PM50

The PM50 can take the place of just about any single-ended power meter. It is great for being able to calibrate RF power amps, verify output levels, and even test nearby transmitters for signal strength.

The obvious thing to do with the PM50 is measure power. Many RF amplifiers will age over time and their characteristics will change so that they will need tuning to maintain their rated outputs. Use the PM50 as a dummy load so that you can calibrate without transmitting anything over the air. Transmitting over the air is not something you want to do while calibrating! Typically you would tweak some trim caps or coils to “bring up” the power to a more acceptable level.

You can also check modulation levels for sideband and CW because the meter is fast enough to find your peak power and display that value for you. You can immediately tell if you are overmodulating, how much power you could make a contact with, etc.

For signal strength measurements you will usually use a calibrated antenna. A calibrated antenna has very specific known characteristics. A reading can be taken from the PM50 which can then be plotted against its characteristic curve to give a precise field strength measurement. Through this you can determine whether a transmitter is within specifications or not, and you can plot coverage from a transmission site. To make readings even more accurate, a bandpass filter would be used to reject signals other than the one you are interested in.

This also serves as a quick check for proper operation of two-way radios; Simply run a patch cable between your two-way and the PM50 and key the radio. See what the display shows you and you will have a good indication of how well the radio is operating! You can also tell immediately if your antenna is broken if you have plenty of transmission power but no coverage.

This kit is basically used in place of a standard analog meter movement

OPERATION OF THE PM50

Operation of the PM50 is fairly simple, requiring little of your precious brainpower to figure out. When any of the LEDs are on, you are in power in watts mode. When no LEDs are on you are in dBm mode.

For example let’s say the middle LED is on and the display reads 1.50. The middle LED represents milliwatts, so we have 1.50 milliwatts. Another example is if the far left LED is lit and the display reads 35.4; this means you are reading 35.4 watts. Not too hard is it?

Now, if you have no LEDs on and the display reads –12.4 this means you are reading –12.4dBm. dBm is a measure of dB in respect to 1.0 miliwatt, which is 0dBm. Anything over 1.0 miliwatts is positive, anything below is negative. An increase of 10 in dBm is an increase of a factor of 10 in power. This means an increase of 30dB is the same as an increase in power of 1,000. This means 1.0 miliwatts increased by 30dB is 1 watt.

○ ○ ○ Units: dBm

○ ○ ● Units: microwatts (Reading * 0.000001)

○ ● ○ Units: milliwatts (Reading * 0.001)

● ○ ○ Units: watts (Reading x 1.0)

TROUBLESHOOTING

PROBLEM: I only get ——.– as a reading, no matter what.
SOLUTION: Be glad your display is working! Now you can worry about the rest. First you will want to go back to the calibration stage for assembly. It is probably calibrated incorrectly or not at all. Primarily, if the calibration is set too low you need a lot of level to overcome the threshold. Otherwise it may be that your cable assembly is shorted or loose. Check the cable assembly to make sure things are not loose inside the strain relief. You can also use a continuity meter to make sure the tip is connected to the tip, ring to ring, etc. But also make sure a ring isn't connected to a tip.

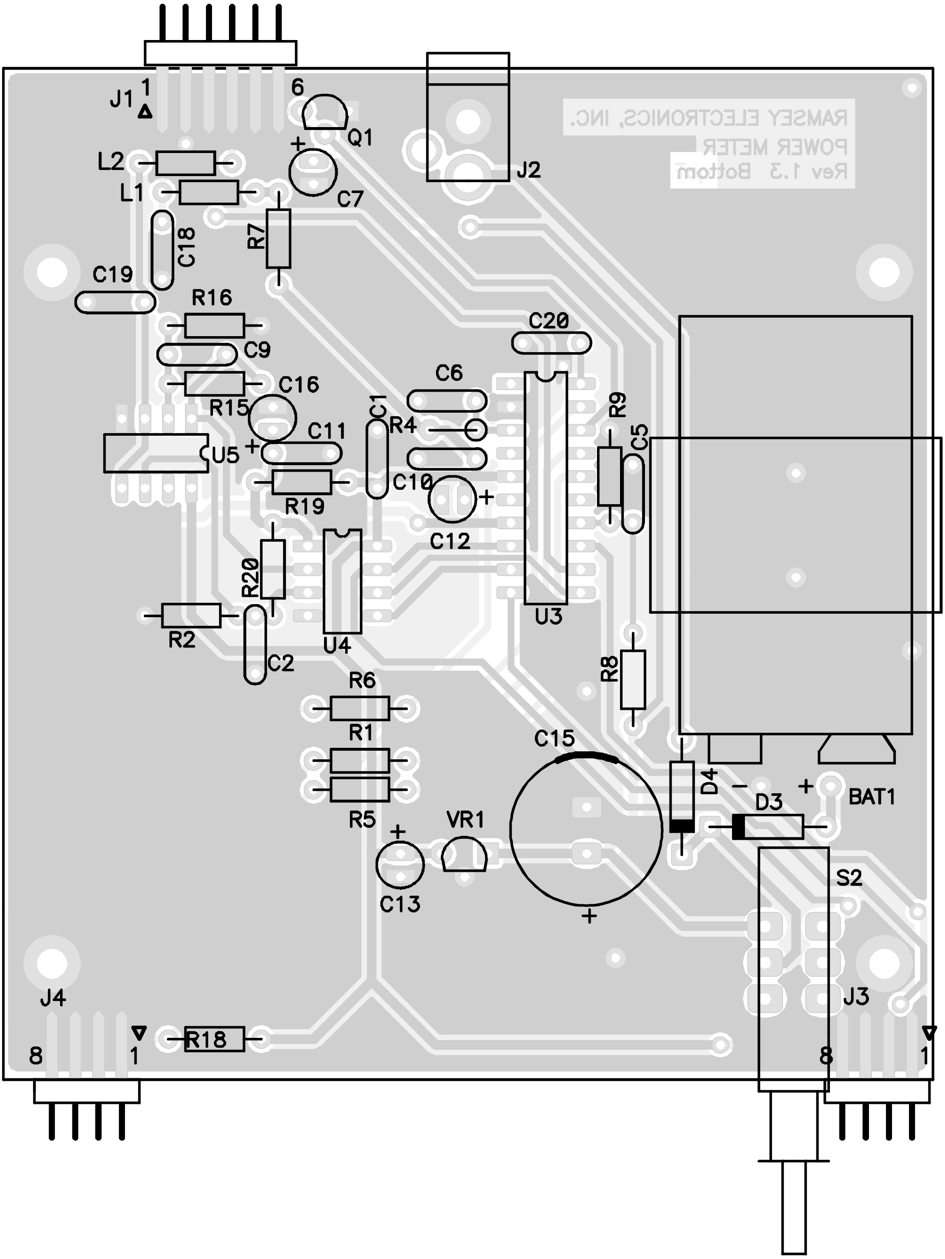
PROBLEM: The display shows me nothing.
SOLUTION: This could be a result of a variety of problems. The first thing we will check is the power source so you will need a voltmeter here. Check pin 8 of U5 for +5V when the power is switched on. If not, check for solder bridges or opens. Also check your battery wiring and your battery. Make sure the battery jack is installed in the correct orientation. The battery should read at least 8V when the power is off.
If power checks out but still no display, check the mounting between the main board and the display board. You may have a short between one of the signal lines and data cannot get to the LCD controller. Also check to make sure you installed the display in the correct orientation. If you goofed this up, it is very difficult to fix. You will need to unsolder the display one pin at a time to remove it, and then straighten out all of the pins, and install it in the other direction.

PROBLEM: The display shows me power, but it is way off!
SOLUTION: This can be a problem, since calibration is dependant on the fact that there aren't a lot of strong signals in the vicinity of your unit while you are calibrating. If you have a good signal generator, you will want to set the generator output to +0dBm, and turn R2 on the detector board so the display matches it. If you are unable to find a good generator and cannot accurately calibrate the unit send it in to us, and for a small fee (call us!) we will calibrate and test it for you.

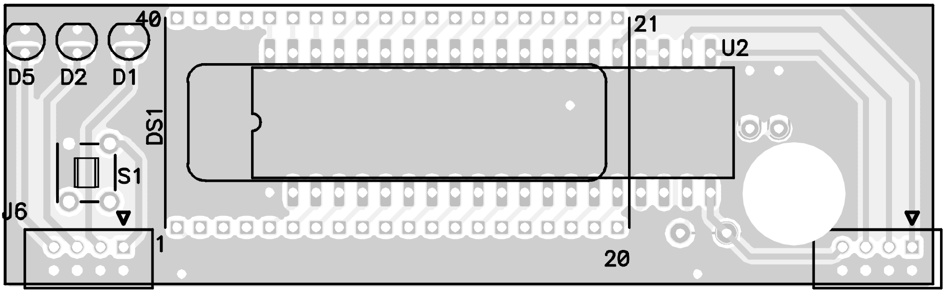
PROBLEM: The fan doesn't run.
SOLUTION: Normally the fan doesn't run since it only comes on when needed and if the detector doesn't pick up more than 5 watts for a period of time it will never run at all. Try transmitting 5 watts or more into the detector for at least 10 seconds, the fan should start to run. If the fan still doesn't run check the plug position so that black = pin 1.

PROBLEM: I just can't make the &#^$^@! Thing work!
SOLUTION: Call Ramsey Support at 1-585-924-4560 or look at the Warranty in this manual. We are here to help and to reduce your frustration as much as possible. It usually is something simple. These DO work, I promise!

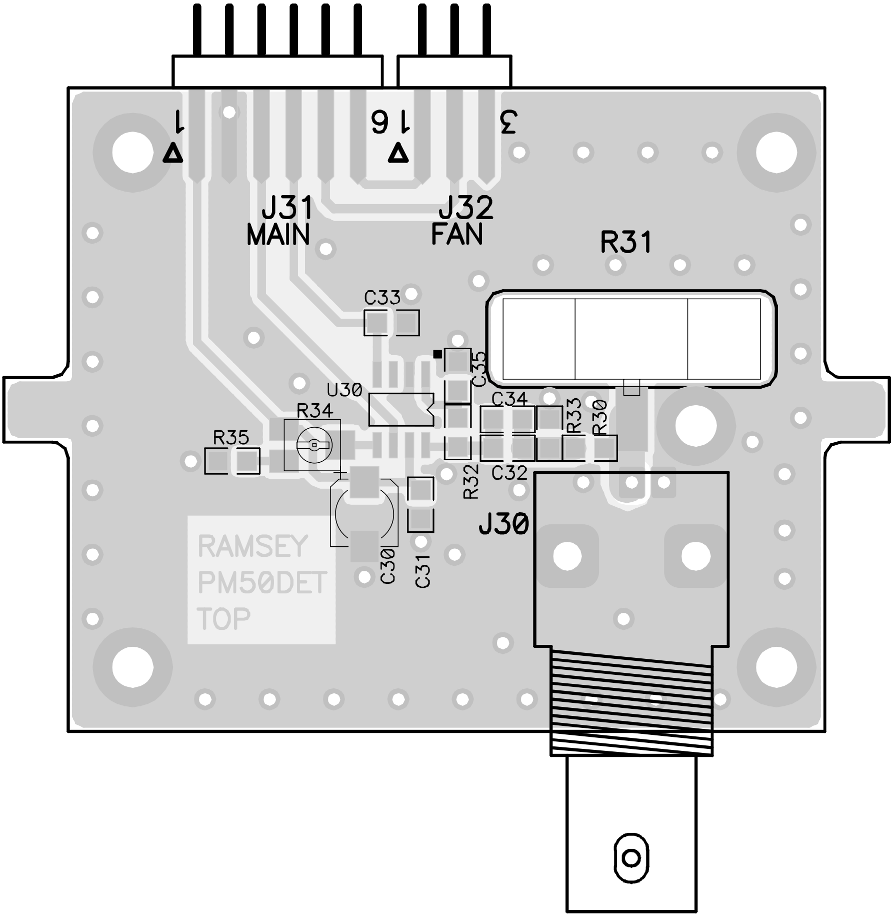
MAIN BOARD LAYOUT



DISPLAY BOARD LAYOUT



DETECTOR BOARD LAYOUT



The Ramsey Kit Warranty

Please read carefully BEFORE calling or writing in about your kit. Most problems can be solved without contacting the factory.

Notice that this is not a "fine print" warranty. We want you to understand your rights and ours too! All Ramsey kits will work if assembled properly. A team of knowledgeable people have field-tested several "copies" of this kit straight from the Ramsey Inventory. If you need help, please read through your manual carefully. All information required to properly build and test your kit is contained within the pages!

1. DEFECTIVE PARTS: It's always easy to blame a part for a problem in your kit, Before you conclude that a part may be bad thoroughly check your work. Today's semiconductors and passive components have reached incredibly high reliability levels, and it’s sad to say that our human construction skills have not! But on rare occasions a sour component can slip through. All our kit parts carry the Ramsey Electronics Warranty that they are free from defects for a full ninety (90) days from the date of purchase. Defective parts will be replaced promptly at our expense. If you suspect that any part is defective, please mail it to our factory for testing and replacement. Please send only the defective part(s), not the entire kit. The part(s) MUST be returned to us in suitable condition for testing. Please be aware that testing can usually determine if the part was truly defective or damaged by assembly or usage. Don't be afraid of telling us that you 'blew-it', we're all human and in most cases, replacement parts are very reasonably priced.

2. MISSING PARTS: Before assuming a part value is incorrect, check the parts listing carefully to see if it is a critical value such as a specific coil or IC, or whether a RANGE of values is suitable (such as "100 to 500 uF"). Often times, common sense will solve a mysterious missing part problem. If you're missing five 10K ohm resistors and received five extra 1K resistors, you can pretty much be assured that the '1K ohm' resistors are actually the 'missing' 10 K parts ("Hum-m-m, I guess the 'red' band really does look orange!") Ramsey Electronics project kits are packed with pride in the USA. If you believe we packed an incorrect part or omitted a part clearly indicated in your assembly manual as supplied with the basic kit by Ramsey, please write or call us with information on the part you need and proof of kit purchase.

3. FACTORY REPAIR OF ASSEMBLED KITS:

To qualify for Ramsey Electronics factory repair, kits MUST:

1. NOT be assembled with acid core solder or flux.

2. NOT be modified in any manner.

3. BE returned in fully-assembled form, not partially assembled.

4. BE accompanied by the proper repair fee. No repair will be undertaken until we have received the MINIMUM repair fee (1 hour labor) of $50.00, or authorization to charge it to your credit card account.

5. INCLUDE a description of the problem and legible return address. DO NOT send a separate letter; include all correspondence with the unit. Please do not include your own hardware such as non-Ramsey cabinets, knobs, cables, external battery packs and the like. Ramsey Electronics, Inc., reserves the right to refuse repair on ANY item in which we find excessive problems or damage due to construction methods. To assist customers in such situations, Ramsey Electronics, Inc., reserves the right to solve their needs on a case-by-case basis.

The repair is $50.00 per hour, regardless of the cost of the kit. Please understand that our technicians are not volunteers and that set-up, testing, diagnosis, repair and repacking and paperwork can take nearly an hour of paid employee time on even a simple kit. Of course, if we find that a part was defective in manufacture, there will be no charge to repair your kit (But please realize that our technicians know the difference between a defective part and parts burned out or damaged through improper use or assembly).

4. REFUNDS: You are given ten (10) days to examine our products. If you are not satisfied, you may return your unassembled kit with all the parts and instructions and proof of purchase to the factory for a full refund. The return package should be packed securely. Insurance is recommended. Please do not cause needless delays, read all information carefully.

PM50 HIGH RANGE POWER METER
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REQUIRED TOOLS

- Soldering Iron Ramsey WLC100
- Thin Rosin Core Solder Ramsey RTS12
- Needle Nose Pliers Ramsey MPP4 or RTS05
- Small Diagonal Cutters Ramsey RTS04

<OR> Technician's Tool Kit TK405

ADDITIONAL SUGGESTED ITEMS

- Holder for PC Board/Parts Ramsey HH3
- Desoldering Braid Ramsey RTS08
- Digital Multimeter Ramsey M133

Price: $5.00
Ramsey Publication No. MPM50
Assembly and Instruction Manual for:

RAMSEY MODEL NO. PM50

TOTAL SOLDER POINTS
250

ESTIMATED ASSEMBLY TIME
Beginner ....2 hrs
Intermediate ....1.5 hrs
Advanced ....1.0 hrs

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